S38-37
58

Use of Control Umbilicals as a Deployment Mode for Free Flying Telerobotic Work Systems

J.S. Kuehn and E.D. Selle
ORINTEC
Vallejo, CA 94590

ϕ1932435

1. ABSTRACT

Work to date on telerobotic work systems for use in space generally consider two deployment modes, free flying, or fixed within a limited work envelope such as at the end of the RMS. Control tethers may be employed to obtain a number of operational advantages and added flexibility in the basing and deployment of telerobotic work systems.

Use of a tether allows the work system to be separated into two major modules, the remote work package and the control module. The Remote Work Package (RWP) comprises the free flying portion of the work system while the Control Module (CM) remains at the work system base.

The chief advantage of this configuration is that only the components required for completion of the work task must be located at the work site. Reaction mass used in free flight is stored at the Control module and supplied to the RWP through the tether, eliminating the need for the RWP to carry it. The RWP can be made less massive than a self contained free flying work system. As a result, reaction mass required for free flight is lower than for a self contained free flyer.

The lower mass of the RWP also reduces the risk of collision damage to the object being worked on. Critical components of the work system are located away from the work site and line of sight communications are better assured. When based on a manned platform, these critical components may be kept within reach of a human operator.

Using TRIV, a conceptual Teleoperated Remote Inspection Vehicle, this paper compares the operational aspects free flight and RMS deployment of work vehicles with deployment using a control umbilical for various basing alternatives. Critical subsystems such as the tether, the tether management system, and the RCS thruster control system are discussed within the framework of the TRIV concept.

2. INTRODUCTION

Telerobotic work systems will become an important tool for the support of future space programs. All such systems will have some means to navigate to and from and maneuver around the work site. A communication and control link between the work system and the operator also is required. These key subsystems can be considered the backbone of any telerobotic work system. Without these, the flexibility of the remote work system is severely impaired.

Unless the work piece can be positioned within the working envelope by the vehicle's manipulators, maneuvering about the work site will be a major portion of any task. If access is limited, docking points are inconveniently located, or tool reaction points are ill placed, the requirement for maneuvering will increase dramatically. All of these conditions can be expected to occur under actual conditions.

Choices made about the configuration of the work system can have a large impact on its operability and utility. Maneuvering, communication and control are the foundation of any telerobotic system, and should be considered as carefully as manipulators and tooling when a telerobotic work system is defined.

Remote work system definition studies to date have primarily assumed that the work system will be deployed as a free flyer or as a work package carried by the Remote Manipulator System. While both are viable, each has its advantages and drawbacks.

Free flying vehicles which are connected to the control site by a tether provide many advantages over other deployment modes, especially when the work vehicle is based and operated from a manned platform. The tether acts both as a control and communication link between the operator and the vehicle. More importantly, vehicle power and reaction mass are also supplied to the vehicle by the tether.

This paper discusses the use of control tethers for space based telerobotic work systems, and the advantages that they offer. The concept of a Tethered Remote Inspection Vehicle (TRIV) is presented as a means of illustrating the use of control tethers.

3. DEPLOYMENT OF TELEROBOTIC WORK SYSTEMS

Development studies of telerobotic work systems for space use have to date considered two modes of deployment for them. Work systems are usually depicted as being positioned by the RMS on the shuttle or Space Station, or they are free flying systems. While each of these has certain advantages, they are not the only way that such a work system can be deployed.

Control tethers can be used in the deployment of telerobotic work systems to great advantage in most situations. While the application of control tethers may seem novel for space work systems, the use of control tethers is far from new. Virtually every teleoperated work system used subsea (with the exception of a few autonomous vehicles) has a control tether. Currently over 300 such vehicles are in commercial operation subsea. Tethered work vehicles are routinely operated subsea in such congested areas such as the inside of offshore platforms.

RMS DEPLOYMENT

Deployment of a work system on the end effector of the RMS requires no reaction mass for maneuvering. It takes advantage of existing proven technology, and provides a positive means of placing the work system.

The major drawback of the RMS system is the limited work envelope that it provides. The geometry of the RMS/work system combination may additionally limit the work envelope, or make it impossible to place the work system in the optimum plane for the completion of the task.

In order to increase that envelope on the Space Station, for example, a movable platform for the RMS is envisioned. Such a system will require significant structural additions to the Station, an increase in mass and complexity of the RMS system. While these additions may be justified by the operational requirements for the RMS, the work envelope is still limited.

FREE FLYING WORK SYSTEM

A work system deployed as a free flyer must be essentially a self contained system. It must carry its own reaction mass and power source, and its mission capability will be directly effected by the amount of each it can carry. Addition of both reaction mass and power capacity to the vehicle are done only with a significant weight penalty.

Control of the free flying work vehicle is also somewhat more complicated by the fact that a secure communications link cannot be guaranteed. Depending on where the vehicle will operate, line of sight communications may be difficult to achieve. As a result, onboard control systems must be capable of handling a loss of communications in a safe manner.

Within the limits of its fuel supply, and acceptable communication time delays, a free flying work system provides an unrestrained work envelope. Deployment of such a system would also represent a major step towards an autonomous vehicle. The free flyer will be a fairly complex and massive work system.

USE OF CONTROL TETHERS

Control tethers may be used in telerobotic work systems as a compromise between free flying and RMS deployment. They offer a number of advantages for the deployment of telerobotic work systems. Use of a tether allows the mass of the work system to be significantly reduced if both power and reaction mass are supplied to the vehicle through the tether.

As a result, reaction mass required for free flight is lower than for a self contained free flyer. Use of the tether also significantly increases the operating envelope as compared to RMS based work systems, and maneuverability is enhanced. The net result is that a tethered system will have a greater mission capability than a similar free flying work system.

Tether deployed work systems would be ideal for use aboard a manned platform like the Space Station. Critical components of the work system are located away from the work site within reach of a human operator, and the line of communications are secure. If problems develop on the work package, it can be retrieved to the platform for maintenance. The tether may also be used to retrieve items grasped and held by the work vehicle.

Control tethers offer additional advantages when used with a free flying propulsion system such as the OMV. When based on the OMV, the system would be divided into two modules, the Remote Work Package (RWP), and the Control and Communication Module (CCM).

The RWP is comprised of systems that are required to do the actual work such as manipulators, vision systems sensors, and related controls. The CCM is comprised of fuel and power storage, data processing, communications equipment, and control systems which are not required to be directly at the work site.

The lower mass of the RWP will reduce the reaction mass required for maneuvering over that required if the work system is rigidly attached to the OMV front end. Since current concepts require that the OMV be maneuvered to position the work system, this savings will be significant. The lower mass of the work package will also reduce the risk of major damage should an uncontrolled contact occur between the work system and the object worked on.

Use of the tether in this situation will also increase work system operability. The OMV can be positioned such that line of sight communications is best assured. In addition, the separation of the OMV and the work package also allows for contingency operations. Should the work package malfunction, it can be retrieved to the OMV. If this is not possible, the tether can be severed as a last resort, and the OMV returned for future use.

4. EXPERIENCE WITH UMBILICAL SYSTEMS

With the exception of life support umbilicals used on early EVAs, there is little experience in space with the type of control tethers proposed. They are, however, commonly used subsea where virtually all teleoperated work systems used are tether deployed. Tethered work systems are routinely operated in and around offshore platforms, drill sites and other congested locations.

Tethers have been designed and used subsea that carry high pressure hydraulic fluid, high voltage power conductors and coaxial and fiber-optic communication conduits. In many cases these tethers are required to carry significant static and dynamic tension loads, and still perform to specification.

While the microgravity environment is unique and different from the subsea environment, much of the experience gained in the deployment of tethered or umbilical work systems can be carried over. As part of this carry over, ORINTEC has taken its knowledge and background in subsea work systems and begun development of a Tethered Remote Inspection Vehicle (TRIV).

5. TETHERED REMOTE INSPECTION VEHICLE (TRIV)

The TRIV concept has been developed along the lines of subsea Remotely Operated Vehicles (ROVs). The TRIV consists of four major system components. These are the vehicle itself, the umbilical or tether, the umbilical management system, and the control system.

VEHICLE SYSTEM

The TRIV vehicle can be broken down further into four major subsystems. The first and simplest is the frame or body. The frame will be an open frame to allow for easy access for maintenance and attachment of specialized mission equipment. This concept of open frame design has been used extensively in the marine environment and has greatly improved maintenance turn around.

The next subsystem is the propulsion system. With the planned delivery of reaction mass through the umbilical, the propulsion system will consist of maneuvering type thrusters and the required control valves to operate them. The system should be a strictly off the shelf component system.

The video system is the "eyes" and purpose for the vehicle to exist. This subsystem would consist of at least one television camera mounted on a Pan and Tilt mechanism. This allows the operator to "look around" without having to constantly move the vehicle. As many cameras can be added to the vehicle as are necessary to accomplish the desired mission. Some examples of configurations could be to have on fixed, forward facing camera for the pilot, and one pan and tilt camera operated by an observer.

The fourth and last subsystem is the control/communication system. This system for a small inspection vehicle may consist of control and television cable terminations with all the electronic control functions residing in the manned control station. For somewhat larger and more complex systems, there may be a video multiplexer, control signal multiplexer, data modems, and actual on board supervisory control logic.

UMBILICAL OR TETHER SYSTEM

The umbilical for the TRIV will be configured dependent on the ultimate mission for the vehicle itself. However, all umbilical configurations will need to have certain properties. These requirements will be to carry power, reaction mass and control information to the vehicle, carry television signal and other data from the vehicle to the operator, and function as a load bearing connection to the vehicle to recover the vehicle and any loads attached to it.

UMBILICAL OR TETHER MANAGEMENT SYSTEM

The umbilical management system will consist of two major components. The first is the winch system. The winch will have a tensioning device and a level wind system to allow for efficient storage and handling of the umbilical. The second major component will be the umbilical payout and automatic control system.

This control system will be a closed loop control system to allow for the efficient payout and take up of the umbilical without operator intervention. The system will need to sense the movement of the vehicle and control the payout and take up based on the vehicle movement. Due to the dynamics of a moving body attached to a tether, the umbilical can not be payed out too slowly or it will hamper the movement of the vehicle. If the umbilical is payed out too quickly, there will be a greater danger of entanglement and damage to the umbilical.

CONTROL SYSTEM AND OPERATOR INTERFACE

The control system for the TRIV will encompass the above mentioned umbilical management system and the operator controls. For the initial concept we do not anticipate any supervisory control built into the vehicle, but some will be used in the master control station.

The operator interface will consist of a joystick to control forward, backward, left, right, and rotation around the vehicles Z-axis.

separate control will control vertical movement and rotation on the X and Y axis. This provides the operator with the most intuitive control of the vehicle. There are no plans to allow the operator direct control of each thruster.

In addition to the vehicle movement control, there will be control of the television camera pan and tilt mechanisms and any other sensors or data aquisition devices.

6. AREAS FOR TECHNOLOGY DEVELOPMENT

Much of the technology described here and/or envisioned to be used in the TRIV exists as off the shelf products today. Much of it must still be space qualified, but the functional designs already exist. Some of the areas that still need development and study are the umbilical management system, the dynamics of the umbilical and the vehicle together in a microgravity environment, and the operator control system.

This development and study work can all be done in laboratories and with computer simulations before venturing into space. We anticipate 12 to 18 months to complete sufficient study and development to be ready for final design of a space ready system. At this time we at OMNITEC have already begun this work and hope to begin final designs in 1988 with a planned operational system by 1989.

7. CONCLUSIONS

The application of control tethers or umbilicals for remote inspection and work systems for use in space has many advantages. These include the mobility of a free flying system with the control link of an RMS deployed system. The experience available from the operators and designers of the subsea work systems can be used to develop microgravity based, tethered vehicles rapidly and inexpensively. An example of this type of development is the Tethered Remote Inspection Vehicle (TRIV). The first prototype of this vehicle should be available by 1989.